

The Swift view of Supergiant Fast X-ray Transients

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Abstract. We report here on the recent results of a monitoring campaign we have been carrying out with *Swift*/XRT on a sample of four Supergiant Fast X-ray Transients. The main goal of this large programme (with a net *Swift*/XRT exposure of ~ 540 ks, updated to 2009, August, 31) is to address several main open issues related to this new class of High Mass X-ray Binaries (HMXBs) hosting OB supergiant stars as companions. Here we summarize the most important results obtained between October 2007 and August 2009.

Keywords: X-ray binaries; accretion and accretion disks

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SUPERGIANT FAST X-RAY TRANSIENTS

The discovery with the *INTEGRAL* satellite of a new class of X-ray Binaries (the Supergiant Fast X-ray Transients, SFXTs) associated with blue supergiant companions and characterized by fast transient X-ray emission [1], has changed the classical view of the HMXBs research field. This new subclass of massive binaries includes 8 members, with ~ 20 candidates (see [2] or <http://isdc.unige.ch/~rodrigue/html/igrsources.html> for a list of new *INTEGRAL* transient sources). These sources show apparently short X-ray outbursts (as observed with *INTEGRAL*), characterized by a few hours duration flaring activity, reaching 10^{36} – 10^{37} erg s⁻¹ at peak, but with no persistent emission, as observed with *IBIS/INTEGRAL*.

Follow-up observations allowed to identify the companions as OB supergiant stars (e.g. [3, 4, 5]).

A few sources were observed with more sensitive instruments (*Chandra* and *XMM-Newton*) outside bright flares, being found in a quiescent state, with a very soft, likely thermal, spectrum and a low X-ray luminosity of $\sim 10^{32}$ erg s⁻¹ (e.g. IGR J17544–2619, [6]).

Spectral properties seem to be very similar to those of accreting pulsars, with a flat power law spectrum below 10 keV, and high energy cutoff around 10–30 keV (e.g. [7, 8]).

Thus, it is often assumed that all SFXTs host a neutron star as compact object, although only in four members a pulse period has been measured: AX J1841.0–0536 ($P_{\text{spin}} \sim 4.7$ s, [9]), IGR J11215–5952 ($P_{\text{spin}} \sim 187$ s, [10]), IGR J16465–4507 ($P_{\text{spin}} \sim 228$ s, [11]) and IGR J18483–0311 ($P_{\text{spin}} \sim 21$ s, [12]). A black hole cannot be excluded in the other members of the class.

The orbital periods have been measured in five sources and range from 3.3 days (IGR J16479–4514, [13]) to 165 days (in IGR J11215–5952, [8, 14, 15, 16]). Two sources display periodically recurrent outbursts, IGR J11215–5952 [8] and IGR J18483–0311 ([17, 12]), suggesting that the outburst is triggered near the periastron passage in a highly eccentric orbit.

Swift CONTRIBUTION

We performed the first long-term monitoring campaign with *Swift*/XRT of a sample of four SFXTs: XTE J1739–302, IGR J17544–2619 (the two prototypes of the class), IGR J16479–4514 and the X-ray pulsar AX J1841.0–0536.

The campaign strategy consists of 2 or 3 XRT pointings per source per week (about ~ 1 ks each) in order to monitor the source status, which was largely unknown (outside the bright outbursts) before these *Swift* observations. Given the structure of the observing plan, this monitoring can be considered as a casual sampling of the source light curves at a resolution of about ~ 4 days (see Table 1 for a summary).

The main aims were to monitor the long-term properties, to catch “almost” every outburst (even the fainter ones, not triggering the *Swift*/BAT), to monitor the onset of a new outburst and to be able, in this case, to follow the whole outburst duration with more frequent subsequent observations (in this respect the *Swift* flexibility is a crucial property), and to get truly simultaneous wide band spectra during bright flares. Our monitoring campaign (still on-going) unveiled several new properties of SFXTs (see details in [18, 19, 20, 21, 22]).

In particular, *Swift* observations have demonstrated that SFXTs spend most of their life still accreting matter even outside bright flaring activity, emitting at an intermediate level of 10^{33} – 10^{34} erg s $^{-1}$, with large variability and an absorbed hard X-ray spectrum (power law photon index of 1–2, or hot black body temperatures of 1–2 keV, observed with XRT below 10 keV).

Besides the bright outbursts (detected also with BAT) and the intermediate level of X-ray emission, several 3σ upper limits were also obtained, either because the source was faint or because of a short exposure due to the interruption by gamma-ray burst events. Thus, to create a uniform subsample for the “non-detections” state, we excluded all observations that had a net exposure below 900 s. An exposure of 900 s corresponds to 2–10 keV flux limits of ~ 1 – 3×10^{-12} erg cm $^{-2}$ s $^{-1}$ (3σ), depending on the source (assuming the best fit absorbed power law model for the intermediate state of each source).

We then defined as *duty cycle of inactivity* (IDC), the time fraction each source spends undetected down to a flux limit of 1 – 3×10^{-12} erg cm $^{-2}$ s $^{-1}$ (which means an upper limit to the time spent in quiescence). The IDCs are the following: 17 % (IGR J16479–4514), 28 % (AX J1841.0–0536), 39 % (XTE J1739–302) and 55 % (IGR J17544–2619).

TABLE 1. Status of the *Swift*/XRT monitoring programme of SFXTs (updated to 2009, August 31)

| | Number of Observations | XRT net exposure (ks) | Number of bright flares | Inactivity Duty Cycle (IDC) |
|-----------------|---------------------------|--------------------------|----------------------------|--------------------------------|
| IGR J16479–4514 | 133 | 152 | 2 | 17 % |
| XTE J1739–302 | 162 | 165 | 3 | 39 % |
| IGR J17544–2619 | 138 | 127 | 4 | 55 % |
| AX J1841.0–0536 | 88 | 96.5 | 0 | 28 % |

For IGR J16479–4514 a contribution to the IDC is due to the X–ray eclipses. One of the main findings of our monitoring is that the quiescence in these transients is a rarer state [22] than what previously thought based only on *INTEGRAL* observations. Accumulating all data for which no detections were obtained as single exposures [22], we could get the lowest luminosity level, which is reached in XTE J1739–302 (6×10^{32} erg s $^{-1}$, 2–10 keV) and in IGR J17544–2619 (3×10^{32} erg s $^{-1}$).

Broad band truly simultaneous spectra (XRT together with BAT) were obtained from 8 bright flares caught from 3 of the 4 monitored sources. The best fits could be obtained with Comptonized models (COMPTT or BMC in XSPEC) or with an absorbed flat power law model with high energy cutoff around 10–30 keV (see [19, 20, 21]). This spectral shape, and in particular the spectral cutoff, is compatible with a neutron star magnetic field of $\sim 10^{12}$ G [23], although no cyclotron lines have been detected yet in the SFXTs we have monitored (but see also [24] for a hint of a cyclotron emission line at low energy in the SFXT IGR J18483–0311).

Variable absorbing column densities were also observed between different outbursts in the same source (XTE J1739–302) and within the same outburst, likely due to local dense clouds of matter composing the supergiant wind.

The SFXTs bright and short flares (a few hour long) are actually part of a longer outburst phase lasting days [20], as already observed in the SFXT IGR J11215–5952 [15].

Optical/UV observations obtained with UVOT simultaneously to *Swift*/XRT monitoring have revealed a possible hint (which needs confirmation) of an UV flaring activity simultaneously to the X–ray bright flares in XTE J1739–302 [22].

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